A GENERATOR SET HAVING AN INVERTER

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a generator set having an inverter and particularly to a generator set having an inverter where a generator of particularly a magnetic type can be operated at high efficiency within a wider range of the revolution.

Description of the Related Art

It has increasingly been common that an engine operated generator for use as an alternating current power source is equipped with an inverter for stabilizing the output frequency. For example, such a generator set having an inverter is disclosed in Japanese Patent Laid-open Publication (Heisei) 11-308896 where an alternating current power is generated by an engine operated generator, converted into a direct current form, and converted again by the inverter into an alternating current form of a commercial frequency. Because its frequency does not depend on the revolution of the engine, the output of the generator set having an inverter can be adjusted to a desired power output which is preset or determined to match the magnitude of load by controlling the revolution of the engine.

Fig. 9 illustrates a power output characteristic of a generator of a magnetic type where the revolution is a

parameter. As shown, the curves A, B, and C represent the relationship between the voltage and the current of the output when the revolution of the generator is expressed by H, M, and L (H>M>L) respectively. The curves Ap, Bp, and Cp represent the outputs of the generator determined by the curves A, B, and C respectively. The direct current voltage at the input of the inverter can thus be controlled to a target level V for maintaining the inverter output to match the load.

As apparent from the drawing, with the direct current voltage at the input of the inverter maintained at the target level V, the outputs of the generator at L, M, and H of the revolution are expressed by the points p', q', and r' respectively designated on the corresponding curves Ap, Bp, and Cp which are defined by the intersections between A and V, between B and V, and between C and V respectively. The power output is almost a maximum level at M of the revolution while is a pre-low level at L of the revolution and a post-low level at H of the revolution. More particularly, the revolution should stay in a narrow range about M for allowing the generator to produce generally a maximum of the output or operate at an optimum efficiency.

When the revolution of the engine is controlled for adjusting the output of the generator, it should be operated within a no-voltage-shortage range, e.g., as shown in Fig. 9, where the voltage is equal to or higher than a target

level V. On the other hand, if the revolution is too high, the power output will be declined due to preferable utilization of the over-current side of the characteristic.

SUMMARY OF THE INVENTION

It is hence an object of the present invention to provide a generator set having an inverter which can be operated in a wider range of the revolution while eliminating the foregoing drawbacks.

As a first feature of the present invention, a generator set having a converter composed of semiconductor rectifying devices for rectifying the power output of a magnetic generator and an inverter for converting a direct current output of the converter into an alternating current form of a particular frequency is provided comprising: a semiconductor rectifying device driving means for controlling the conduction of the semiconductor rectifying devices to maintain the voltage output of the converter at a target voltage level; a revolution detecting means for detecting the number of revolutions of the magnetic generator; and a target voltage setting means for determining the target voltage level so that the target voltage level show a positive characteristic to the revolution detected.

This allows the target voltage level to be set to a lower value at a lower range of the revolution of the magnetic generator and a higher value at a higher range of the same. Accordingly, as the magnetic generator is increased in the

voltage output substantially in proportion to the revolution, it can produce a voltage output of the target level at the lower range of the revolution. Also, its voltage output can be close to the maximum level without lowering the efficiency when the generator is operated at the higher range of the revolution. As a result, the useful range of the revolution of the generator can be increased.

As a second feature of the present invention, a generator set having an inverter may further comprise an engine revolution controlling means for controlling the revolution of an engine to drive the generator so that the conduction rate of the semiconductor rectifying devices is converged on a predetermined target rate, wherein the controlling of the revolution of the engine is implemented by adjusting the supply of fuel to the engine.

This allows the revolution of the engine to be modified within a wider range thus controlling the conduction rate of the semiconductor rectifying devices to a desired level.

As a third feature of the present invention, the engine revolution controlling means may be arranged to decrease the revolutions of the engine when the deviation of the conduction rate from the target rate is positive and increase the same when negative. As a fourth feature of the present invention, a rate of change of revolution of the engine is greater at an increase than at a decrease thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a functional block diagram of a generator set having an inverter showing one embodiment of the present invention;

Fig. 2 is a diagram showing the relationship between the target voltage and the revolution of an engine;

Fig. 3 is a functional block diagram showing a primary part of a thyristor drive unit;

Fig. 4 is a diagram showing the relationship between the target voltage level and the power output of a magnetic generator in the embodiment;

Fig. 5 is a functional block diagram of a primary part of the generator set having an inverter with an output voltage controller of the inverter;

Fig. 6 is a functional block diagram of a primary part of a fuel flow controller;

Fig. 7 is an explanatory view showing the angle of conduction of the thyristors (the rate of conduction of semiconductor devices);

Fig. 8 illustrates the relationship between the deviation of the conduction angle and the adjustment of the target revolution; and

Fig. 9 illustrates the relationship between the target voltage level and the output of a conventional generator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will be described in more detail referring to the relevant drawings. Fig. 1

is a block diagram showing an arrangement of the generator set having an inverter of the embodiment. A magnetic type multi-pole generator 1 (referred to as simply a generator hereinafter) is driven by an (internal combustion) engine 2 to generate a multi-phase (commonly three-phase) alternating current power output. The alternating current power output is full-wave rectified to a direct current form by a converter 3 which comprises a rectifier circuit having thyristors (as semiconductor rectifier devices) connected in a bridge form. The direct current power output is then transferred to an inverter 4 which is connected at its output to and provides an external load 5 with a single-phase power output of a commercial frequency (e.g. 50 Hz). A stepping motor 7 is also provided for controlling the opening of a throttle valve 6 of the engine 2. More specifically, as the opening of the throttle valve 6 is controlled by the number of pulses, it determines the revolution of the engine 2. The engine 2 may be of a fuel injection type of which the revolutions is controlled by the duration of fuel injection.

A voltage detector 8 detects an output voltage of the converter 3. A thyristor drive unit 9 compares the output voltage of the converter 3 with a target voltage level (will be described later in more detail) and determines the conduction of thyristors in the converter 3 using a known manner so that the actual output voltage of the converter 3 detected by the voltage detector 8 is equal to the target

voltage level. This allows the output of the converter 3 to stay at the target voltage level within the controlling range of conduction angle of the thyristors.

The target voltage level is predetermined as a function of the revolution of the engine by the following manner. Fig. 2 is a diagram showing the relationship between the target voltage level and the revolution of the engine. As shown, the target voltage level is set to V0 when the revolution Ne of the engine is lower than 3000 rpm and V1, which is greater than V0, when higher than 5000 rpm. The target voltage level is gradually varied when the revolution Ne ranges from 3000 to 5000 rpm. For example, the target voltage level may be calculated from Equation 1,

$$VDC=145+(Ne/256) \quad \ldots(1)$$

According to the equation 1, when the revolution Ne of the engine is 3000, 4300, or 5000 rpm, the target voltage level is 156.7 V, 161.8 V, or 164.5 V respectively. The calculation of the target voltage level is not limited to the above equation but may be implemented by any appropriate manner where an optimum of the power output can be obtained at a given revolution with relation to the characteristics of the generator.

Fig. 3 is a functional block diagram showing a primary part of the thyristor drive unit 9 assigned with the target voltage level. As shown, a revolution detector 106 measures the revolution Ne. The revolution Ne is then transferred

to a target voltage calculator 91 where it is used for calculating the target voltage level VDC from Equation 1. A voltage deviation detector 92 compares the direct current voltage from the voltage detector 8 or the voltage output of the converter 3 with the target voltage level VDC to determine a deviation from the target voltage level. The deviation is transferred to a thyristor drive circuit 93 for controlling the conduction of the thyristors as explained with Fig. 1.

Because the target voltage level VDC is varied corresponding to the revolution of the engine, the following advantage can be achieved. Fig. 4 illustrates the relationship between the target voltage level VDC and the output of the generator 1, where like items are denoted by like numerals as those shown in Fig. 9. The direct current voltage at the input of the inverter is controlled to be equal to the target voltage level VDC. As apparent, while the direct current voltage level at the input of the inverter is maintained equal to the target voltage level VDC, three different outputs of the generator at L, M, and H of the revolution are expressed by the points p, q(=q'), and r on the curves Ap, Bp, and Cp respectively. As compared with the prior art where the target voltage level is set to a fixed value V, the output at a lower revolution L is increased from r' to r denoted by the arrow and at a higher revolution H from p' to p. Also, the output at a medium revolution M

is substantially at its maximum. More specifically, a high level of the output can be obtained throughout a wider range of revolution. In an experimental example, the range of revolution to be used actually was increased by generally 200 rpm.

As the target voltage level VDC is varied, the input voltage of the inverter 4 may change. This change can be offset more or less by the inverter 4 equipped with a voltage controlling function such as PMW. The PMW technique allows the input voltage of the inverter 4 to stay higher than the least required level but not exceeding the permissive withstand voltage level of the semiconductor devices in the inverter 4.

Fig. 5 is a block diagram showing the voltage controlling function in the inverter 4, where like components are denoted by like numerals as those shown in Fig. 1. As shown, a PWM controller 41 detects the voltage output of the inverter 4 and carries out a PWM action for maintaining the voltage output at a predetermined level.

A fuel flow controller 10 is provided having the following arrangement. Fig. 6 is a functional block diagram of a primary part of the fuel flow controller 10. A thyristor conduction angle detector 101 detects a conduction angle of the thyristors from the control signal which is transferred from the thyristor drive circuit 93 in the converter 3. The conduction angle is continuously measured at equal intervals

of time to calculate its average. The average conduction angle may preferably be a moving average of consecutive data (e.g. of ten times).

The average conduction angle determined by the thyristor conduction angle detector 101 is transferred to a deviation detector 102 where a deviation of the average from a target conduction angle is calculated. The deviation indicates whether or not the generator 1 is operated to produce a generous margin of the output. For the purpose, the target conduction angle may be set to 80 %. The target conduction angle like a common target level has a hysteresis. The target conduction angle may be a fixed degree or may be varied depending on the temperature of the engine 2. For example, when the temperature of the engine 2 is low, the target conduction angle is decreased. As its engine 2 is adjusted to a desired revolution so that the deviation detected by the deviation detector 102 is zero, the generator 1 can be operated to produce a generous margin of the output.

Fig. 7 illustrates a waveform of the thyristor output of the converter 3 driven with the conduction angle of 80 %. As shown, the conduction angle α is an electrical angle corresponding to a duration for conducting the thyristors and can thus be determined by a known manner.

A target revolution updating unit 103 includes a table of revolution adjustment for determining the adjustment of revolution in response to the deviation received as a readout

address from the deviation detector 102.

Fig. 8 illustrates the relationship between the deviation and the adjustment of revolution. The deviation is a difference between the actual conduction angle and the target conduction angle, "actual conduction angle-target conduction angle". The adjustment of revolution determined from the deviation is greater when the deviation is a positive value than that when a negative value. When the deviation is positive, that is, the angle of conduction exceeds the target conduction angle (80%), it is judged that the generator 1 is operated with a less margin. This requires the output of the generator 1 to rapidly respond to a change on the load. When the deviation is negative, the generator 1 runs with a generous margin. Accordingly, the revolution can favorably be inhibited from largely increasing or decreasing which is caused by the effect of overshoot derived from excessive response.

Returning to Fig. 6, the target revolution adjustment value is transferred from the target revolution updating unit 103 to a target revolution storage 104 where it is added with a target revolution stored so that a resultant sum is an updated target revolution. The target revolution is updated not to depart from a range between the maximum and the minimum set in a maximum/minimum revolution setting unit 105. More specifically, if the target revolution after addition with the target revolution adjustment value is out

of the range, the maximum or minimum of the range will be assigned as the adjusted target revolution. It is noted that because the thyristor conduction angle may be varied at a lower revolution by any small change in the revolution, the minimum of the range has to be specified to ensure the stability of operation with no load or less load.

The revolution of the generator 1 is measured by the revolution detector 106. From the actual revolution received from the revolution detector 106 and the target revolution received from the target revolution storage 104, a control calculator 107 calculates a control value such that the deviation of the actual revolution from the target revolution is zero, using a known manner (e.g. comparison, integration, or differentiation). A throttle controller 108 is connected to a stepping motor 7 and responsive to a resultant output of the control calculator 107 for calculating the number of pulses to drive the stepping motor 7. The stepping motor 7 is thus driven by the number of pulses to change the opening of the throttle valve 6.

In the embodiment, the average conduction angle for the thyristor bridged rectifying circuit is favorably controlled to a predetermined level (for example, 80 %) by modifying the revolution of the engine 2 to determine the output of the converter 3. This allows the generator 1 to be constantly operated to produce a generous margin of the output. More particularly, when the load is increased, the voltage output

of the converter 3 declines. In response to a signal of the declination, the conduction angle of the thyristors can be increased to offset an increase in the load. Simultaneously, as the conduction angle increases, the revolution of the engine 2 can be increased gradually but not rapidly. Because the engine is not frequently changed in the revolution, its generation of noise and consumption of fuel can successfully be reduced.

Also in the embodiment, the voltage output of the converter is measured at the input of the inverter. This eliminates the need of calculating an optimum revolution of the generator or engine with the use of parameters including the effective power output of the inverter, the conversion efficiency of the inverter, the power output for a revolution, and variations between the components in the generator or the effective power detector, hence facilitating the process of controlling. Moreover, the converter in the embodiment for rectifying the current output of the generator is not limited to the described thyristor bridged type but may be of any other voltage controlled type such as DC-DC voltage conversion type.

As set forth above, the feature defined in claim 1 of the present invention allows the target voltage level to be decreased when the generator runs at a lower number of revolutions, thus enabling the operation at a lower range of revolution. Also, as the target voltage level is increased

when the generator runs at a higher revolution, the operation at a higher range of revolution can be ensured without lowering the efficiency.

The feature defined in claim 2 of the present invention allows the revolution of the engine to be modified throughout its range, thus controlling the conduction to a desired rate. Moreover, the features defined in claims 3 and 4 of the present invention permit the power output to be increased or decreased at a proper speed of response corresponding to a change in the load.